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OFFICE OF
THE ADMINISTRATOR

October 29, 1991

Honorable William K. Reilly
Administrator
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

Subject: Leachability: Recommendations and Rationale for Analysis of Contaminant Release

Dear Mr. Reilly:

The Leachability Subcommittee (LS) of the Science Advisory Board's Environmental Engineering Committee (EEC) has prepared the attached recommendations and rationale on leachability, an important release term related to solid wastes and contaminated soils, for your consideration.

Over the past decade, the EEC has reviewed a number of EPA issues involving leachability phenomena and noted several problems relating to this release term that were common to a variety of EPA offices. The Committee believed that these common problems would be best called to the Agency's attention through a general review of leachability phenomena.

Drafts of this report on leachability have been reviewed at a series of Subcommittee, Committee, and Executive Committee meetings over the past 18 months. This included both a session on February 26, 1990, devoted to assessing the Agency's varied needs on leachability-related information, and a Technical Workshop on May 9, 1990. The workshop assisted in determining how leachability phenomena should be used to determine how a waste will leach when present under various scenarios in the environment.

The following recommendations have been developed. First, in regard to leachability test development we recommend:

a) incorporation of research on processes affecting leachability into EPA's core research program to better define and understand principal controlling mechanisms,

b) development of a variety of contaminant release tests, rather than focusing on mimicking a single scenario,

c) development of improved release and transport-transformation models of the waste matrix to complement the leaching tests, and

d) field validation of the tests and models, and establishment of release-test accuracy and precision before tests are broadly applied.

Next, in regard to the application of such tests and models, we recommend:

e) use of a variety of contaminant release tests and test conditions which incorporate adequate understanding of the important parameters that affect leaching in order to assess the potential release of contaminants from sources of concern. A medical analogy is that no physician would diagnose on the basis of one test showing only one aspect of the problem,

f) development of a consistent, easily applied, physical, hydrologic, and geochemical representation for the phenomenon or waste management scenario of concern,

g) identification and application of appropriate environmental conditions for tests in order to evaluate long-term contaminant release potential as required under varying statutes, and

h) coordination between the Agency's programs which develop leachability tests with those that develop the environmental models in which the release terms are used.

Finally, we recommend:

i) establishment by the Agency of an inter-office, inter-disciplinary task group, including ORD to help implement these recommendations, and

j) development of an Agency-wide protocol for evaluating release scenarios, tests, procedures, and their applications.

These recommendations are made with the anticipation that an improved understanding of the fundamental scientific principles that control contaminant release and transport within a waste matrix will allow better regulatory and technical decisions to be made in cases where the potential exists for leaching of contaminants into the environment.

We are pleased to be of service to the Agency, and hope that you will find this effort useful. We look forward to your response to the recommendations cited above.

Raymond C. Loehr

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Executive Committee

Richard A. Conway

Mr. Richard A. Conway, Chairman
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United States
Environmental
Protection Agency

Science Advisory
Board (A-101)

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EPA

LEACHABILITY PHENOMENA

RECOMMENDATIONS AND RATIONALE FOR ANALYSIS OF CONTAMINANT RELEASE BY THE ENVIRONMENTAL ENGINEERING COMMITTEE

ABSTRACT

The Leachability Subcommittee (LS) of the Environmental Engineering Committee (EEC) of the EPA Science Advisory Board (SAB) conducted a self-initiated study and prepared a report on the topic of leachability phenomena. The intent of this report is to provide recommendations and rationale for analysis of contaminant release to the staff in the various offices of the Environmental Protection Agency (EPA). The nine recommendations from the report are highlighted as follows:

1) A variety of contaminant release tests and test conditions which incorporate adequate understanding of the important parameters that affect leaching should be developed and used to assess the potential release of contaminants from sources of concern.

2) Prior to developing or applying any leaching tests or models, the controlling mechanisms must be defined and understood.

3) A consistent, replicable and easily applied, physical, hydrologic, and geochemical representation should be developed for the waste management scenario of concern.

4) Leach test conditions (stresses) appropriate to the situations being evaluated should be used for assessing long-term contaminant release potential.

5) Laboratory leach tests should be field-validated, and release test accuracy and precision established before tests are broadly applied.

6) More and improved leach models should be developed and used to complement laboratory tests.

7) To facilitate the evaluation of risk implications of environmental releases, the Agency should coordinate the development of leach tests and the development of models in which the release terms are used.

8) The Agency should establish an inter-office, inter-disciplinary task group, including ORD to help implement these recommendations and devise an Agency-wide protocol for evaluating release scenarios, tests, procedures, and their applications.

9) Core research on contaminant release and transport within the waste matrix is needed.

<u>Key Words:</u> leachability, leachability phenomena, leach tests and methods, leaching chemistry, leaching models

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I. EXECUTIVE SUMMARY

In waste management, including managing the effects of spills or other releases which are sources of underground contamination, a critical issue is the assessment of the potential for constituents to leach to the environment. The Environmental Engineering Committee (EEC) of the Science Advisory Board (SAB) undertook a study of this issue because it noted several common problems relating to this release term as it reviewed, over the past decade, various leaching tests and risk models for several EPA offices. Tests such as the Extraction Procedure (EP) and the Toxicity Characteristic Leaching Procedure (TCLP) had, and continue to have, scientific limitations, yet were being inappropriately and in some cases widely used. Often tests were developed without rigorous review. A self-initiated study seemed appropriate to define the leachability problem better and to offer advice on its resolution.

The EEC established a Leachability Subcommittee (LS) that addressed:

1) Needs of the Agency and regulated communities to quantify leachability (releases) of contaminants to the environment.

2) State-of-the-art and science related to fundamental principles and practice in predicting leaching of constituents from wastes, contaminated soils, and other sources.

3) Recommendations to improve the scientific understanding and application of leaching tests.

Workshops were held, literature was analyzed, and findings were discussed over an 18-month period leading to the preparation of this report.

The various needs for tests and models to predict leaching are defined. Tests developed and used in the U.S. and Canada are summarized. The scientific considerations important in design and interpretation of leachability tests are presented. This information, expert advice and analysis by workshop participants, and reviews by SAB members, resulted in guidance which should, if progressively implemented, significantly strengthen the Agency's ability to assess appropriately leaching of contaminants from hazardous wastes, contaminated soils and other sources.

This guidance, in the form of nine recommendations, is summarized as follows:

1) A variety of contaminant release tests and test conditions which incorporate adequate understanding of the important parameters that affect leaching should be developed

and used to assess the potential release of contaminants from sources of concern.

2) Prior to developing or applying any leaching tests or models, the controlling mechanisms must be defined and understood.

3) A consistent, replicable and easily applied, physical, hydrologic, and geochemical representation should be developed for the waste management scenario of concern.

4) Leach test conditions (stresses) appropriate to the situations being evaluated should be used for assessing long-term contaminant release potential.

5) Laboratory leach tests should be field-validated, and release test accuracy and precision established before tests are broadly applied.

6) More and improved leach models should be developed and used to complement laboratory tests.

7) To facilitate the evaluation of risk implications of environmental releases, the Agency should coordinate the development of leach tests and the development of models in which the release terms are used.

8) The Agency should establish an inter-office, inter-disciplinary task group, including ORD, to help implement these recommendations and devise an Agency-wide protocol for evaluating release scenarios, tests, procedures, and their applications. The task group should also be charged with recommending what the appropriate focal point(s), responsibilities, and organizational, budgetary and communication links should be within the Agency for the most effective, continued and ongoing support and pursuit of the research, development and utilization of methods and procedures.

9) Core research on contaminant release and transport within the waste matrix is needed.

II. INTRODUCTION

In both hazardous and non-hazardous waste management, one of the most critical issues is the assessment of the potential for constituents contained in the source material to leach or otherwise be released to the environment. Approaches to estimate potential release of organic and inorganic constituents and their subsequent environmental migration and associated health risks are important in many situations (e.g., pollution prevention, risk reduction, restoration-remediation and hazard identification).

This review has been initiated by the Environmental Engineering Committee of the Science Advisory Board because 1) the Committee has been reviewing Agency actions which require definition of the potential for releases from wastes and their transport to human and environmental receptors where exposure can occur, and 2) the Committee has previously reviewed the scientific and technical basis for two tests for leaching potential intended for particular uses: the Extraction Procedure (EP) and the Toxicity Characteristic Leaching Procedure (TCLP) (See for instance, US EPA, Science Advisory Board, Report of the Environmental Engineering Committee, Report on the Review of EP-III, A Procedure for Determining the Leaching Potential of Organic Constituents from Solid and Hazardous Wastes, July 19, 1984). In addressing and reviewing Agency proposals, the Committee has repeatedly observed and commented on the scientific limitations of the EP and TCLP tests. Many of the proposed uses for the tests have been inappropriate because the waste management scenarios of concern were not within the range of conditions used in the development of the tests themselves.

In most cases of inappropriate use of the EP or TCLP tests, the justification given was that it is necessary to cite "standard" or "approved" methods. Even if it is acknowledged that the tests cannot be applied without significant change in the test protocol itself, the need to use a previously "approved" test has been cited.

In a contradictory set of pressures, some offices have devised new tests to suit particular needs, e.g., the "oily waste extraction test," when it was considered necessary. Only rarely have such new or modified leaching tests been subjected to a rigorous review of their precision, accuracy or technical bases comparable to that applied to the EP and TCLP tests.

There are many laboratory tests that have been devised to obtain estimates of the potential for contaminant release. These tests are generally characterized as either static or dynamic. In all instances, aqueous solutions have been utilized as the leaching fluid. Solid-to-liquid ratios of 2:1 to 20:1 have been prescribed. Leaching times of 18 hours to several days, and in some tests, years are required. Various tests specify single to over 20 extractions, and particle sizes from 2 mm to monolith proportions. Table 1 (page 20), provides a summary of over 30 tests designed to help determine the potential for contaminant release. Although a wide range of leaching tests exist, a conceptual framework for their application is generally lacking.

In preparing this report, the Committee has sought the best technical input available on "state-of-the-art" knowledge of the leaching phenomenon. It has also sought and received extensive information on the needs of regulatory and enforcement programs for reliable leaching predictions and their interpretations.

Building on its previous experience in technical reviews, on outside input, and on its own expertise, the Committee offers advice on ways to resolve the conflict between the need for "standard" tests and the need for tests better adapted to the circumstances to which the data are to be applied.

This self-initiated study focused on the following three questions:

1) What are the needs of the Agency and regulated community to quantify leachability or release of contaminants to the environment?

2) What is the state-of-the-art and science dealing with the fundamental principles that should be considered in predicting leaching of chemicals from wastes, contaminated soils, and other sources?

3) What should be or could be done to improve the scientific understanding and application of leaching tests in future risk analysis?

III. WHAT ARE THE NEEDS OF THE AGENCY AND REGULATED COMMUNITY?

The Subcommittee convened a one-day session on February 26, 1990, in Washington, D.C., devoted to assessing the Agency's and other's (private sector and citizen groups) varied needs for leaching tests and information. The findings are summarized in Table 2 (page 25) and are detailed in Appendix C (pages 35-45). Table 2, summarizes the Subcommittee's understanding of the wants, uses, and needs for leachability tests/data within the Agency. At least six program offices have expressed interest in such information. The wants, or what the program offices would like, are varied. Most focused on a means to predict field conditions. All offices expressed a desire for a method(s) to appropriately classify a waste. Given that such a test(s) did exist, the offices would use it such as to set standards, primarily through simulating risk. The Office of Toxic Substances appears to have the broadest uses. Just as the wants and uses are varied, so too are the needs. Consistently, all offices see leachability tests as a means of demonstrating compliance; a use for which most leaching tests were not originally intended.

The EPA, through mandates of the RCRA, CERCLA, CWA and associated regulatory programs, has required chemical testing and other laboratory procedures to predict the possible hazards of chemicals potentially released into the environment. The intent of leaching/extraction tests is to reliably estimate the potential amount and/or rate of contaminant release under worst case environmental conditions, thus enabling remedial, prevent-ative and anticipatory management actions to be taken to protect human health and the environment.

IV. ASSESSMENT OF CURRENT PRACTICE

The Committee assessed the state-of-the-art in leachability determinations through several means:

a) Participation in a Workshop on Contaminant Migration at Rice University on December 15-16, 1989, organized by the National Center for Ground Water Research for the EPA Robert S. Kerr Environmental Research Laboratory in Ada, OK., in cooperation with the University of Texas at Austin and the Electric Power Research Institute.

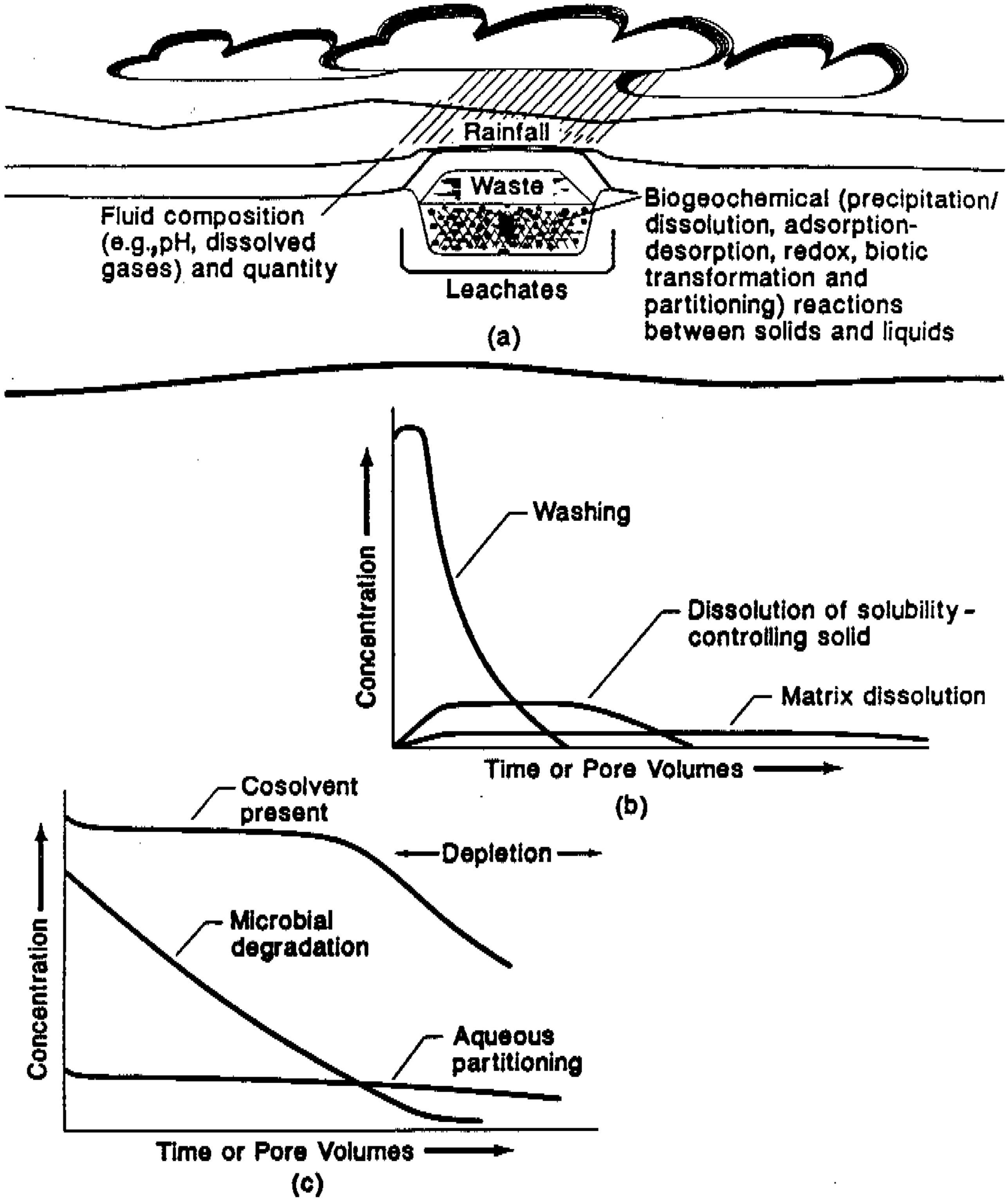
b) Holding a Leachability Workshop under the auspices of the US Environmental Protection Agency, Science Advisory Board on May 9, 1990 in Washington, D.C. The Workshop Program and list of speakers are given in Appendix B, page 34.

c) Review of key references assessing current leachability tests, e.g., Compendium of Waste Leaching Tests, Wastewater Technology Centre, Environment Canada, May 27, 1989 (See Table 1, page 20 for summary of extraction tests).

The findings reported also reflect the personal experiences and expertise of the members of the Leachability Subcommittee.

The Leachability Workshop was conceived as a vehicle for knowledgeable scientists, engineers and practitioners in the field to focus on the scientific principles and issues relating to leachability. The purpose of the Workshop was to conduct a review of the scientific principles involved with leachability phenomena. Various experts discussed relevant topics such as test methods, their descriptions and capabilities for application to the leaching of organics and inorganics, the leaching of stabilized materials, physical-chemical mechanisms, leaching chemistry of organics and inorganics, and alternative approaches to laboratory tests.

The Workshop assisted the Leachability Subcommittee in summarizing the fundamental scientific principles that control leachability (Appendix B, page 34, and Figure 1 page 6), and determining how they can be applied to predict the extent to which contaminants will leach when disposed under various potential environmental scenarios. The Contaminant Migration Workshop, the Leachability Workshop, and the review and assessment of key references, provided the background for formulation of recommendations on how basic principles can be



FIRGURE 1. Conceptual View of Leaching in a Waste Unit.
(a) Generation of leachates;
(b) Potential leaching stages for inorganic contaminants;
(c) Generation of organic leachates.

used on a consistent basis for improving or developing decisions related to leachability.

A conceptual view and summary of the major processes and interactions that can occur in leaching of a waste matrix is presented schematically in Figure 1, page 6. The generation of leachates is depicted (Figure 1a) and is the sum of several geochemical processes involving reactions within a physical mixture of different forms of the same element. For example, in fly ash, an element such as cadmium may occur as simple oxide salts accumulated on the surface of ash particles, as an element within the glass matrix, and as a post-combustion product of aqueous reaction such as $CdCO_3$. Potential leaching stages areillustrated for an inorganic contaminant in Figure 1b. Reaction of the readily available and highly soluble fraction, such as the surface oxide salts, provides high solute concentration during initial washing or leachate generation. This stage is followed by considerably decreased concentrations of solutes as the readily available fractions have been leached or transformed into less soluble forms (such as the $CdCO_3$). These transformed solids are referred to as solubility-controlling solids. Dissolution and depletion of these solubility controlling solids and the bulk matrix are important determinants of the temporal change and characteristics in leachate generation following initial washing.

The generation of organic leachates (Figure 1c) also involves several biogeochemical processes. For example, the leachate concentration of an organic compound may be controlled by its water solubility (aqueous partitioning). However, in the presence of a cosolvent, the leachate concentration is usually controlled by the solubility of the constituents in the organic phase rather than in water and may be substantially increased. Microbial degradation, abiotic transformations and physical partitioning to gaseous and solid phases can further alter the pattern of leachate generation.

V. RECOMMENDATIONS FOR IMPROVED LEACHABILITY DETERMINATIONS TO FILL GAPS BETWEEN NEEDS AND CURRENT PRACTICES

Based on a broad-ranging review and analysis of needs and information available on leaching phenomena, the Leachability Subcommittee has developed the following recommendations:

1) A variety of contaminant release tests and test conditions which incorporate adequate understanding of the important parameters that affect leaching should be developed and used to assess the potential release of contaminants from sources of concern.

In scientific and technical terms, no "universal" test procedure is likely to be developed that will always produce credible and relevant data for input to all decision making exercises. There is nothing inherently bad about having a wide variety of test conditions and methods, to cover the range of needs, if each is defensible in view of the scientific and technical understanding of the basic processes involved. Provisions for adequate margins of safety and varied scenarios should be made. A wealth of knowledge already exists which can form the essential basis for quantitative determinations of the release of contaminants. Appropriate physical, chemical and biological factors should be selected for a specific test or model to reliably estimate contaminant releases. Important information includes: waste characteristics, mobilizing fluid characteristics, intrinsic behavior of chemicals, and most likely reactions to occur under varying hydrologic, chemical and atmospheric conditions (Table 3, page 27).

Chemical and physical characteristics of a waste are significant determinants of leachate composition. The nature and conditions of occurrence of leachable constituents, rather than the total amounts, often dictate the consequential release of contaminants from the waste. Moreover, the speciation of constituents of concern, for example, heavy metals, cannot or has not in most cases been reliably quantified. This can confound reliable anticipation of potential contaminant release, further contributing to uncertainty in contaminant release assessment. Waste or matrix heterogeneity is another complicating factor.

In addition to waste and matrix characterization, it is similarly important to characterize the leaching medium (i.e.,the fluid) which contacts the waste material. Terrestrial porewaters, including groundwaters, have broadly defined fluid parameters and show tremendous diversity in those characteristics which influence solubility and chemical behavior of mobilized waste chemical constituents. Also, fluid which contacts the waste can be influenced by the presence of contaminants from other wastes, such as at a Superfund site where waste oil has been codisposed with PCBs.

2) **Prior to developing or applying any leaching tests or models, the controlling mechanisms must be defined and understood.**

Contaminant release (and eventual fate) in a field environment is an extremely complex phenomenon involving multiple phases and multiple constituents. In order to provide a proper conceptual framework for a leachability scenario, a recommended first step in any leaching test or model should be to identify all significant mechanisms that can ultimately determine release and environmental fate of the contaminants.

After identifying mechanisms, an understanding of how they (directly or indirectly) influence release and environmental fate should be established. Past experience suggests that identifying the principal controlling mechanisms is often straightforward. However, anticipating the interrelationships among concurrent and often competing mechanisms can be much more difficult, yet critical in the characterization of leachability.

In developing the conceptual framework for a leachability scenario, attention should be given to accounting for all significant phenomena -- be they physical, chemical, or biological --and their potential interactions. At a minimum, the following phenomena should be considered: fluid characteristics and flow dynamics, source matrix morphology and chemistry, chemical reactions (equilibrium or kinetic), biotic reactions, and temporal and spatial dependence. These are discussed in relation to the principles identified throughout this report (see also Figure 1 and summary Tables 1, 2 and 3 for overview information).

To understand and predict the leaching of organic constituents of concern, it is important to consider the presence of organic solubilizers such as solvents and oil in addition to wastes. Under the conditions of codisposal with solubilizing agents, the extent of leaching is usually controlled by the solubility of the constituents in the organic phase rather than in water. However, dissolved solvents can, to a lesser extent, affect constituent solubility in the aqueous phase.

Experimental data obtained over the last decade indicate that the solubilizing effect of some agents can dramatically increase the concentrations of normally insoluble organic constituents. In some instances, organics have been shown to enhance the mobility of inorganic constituents, most likely through complexation. In these cases, aqueous extractions to estimate the extent of leachability of the waste may seriously underestimate the magnitude of release for constituents of concern.

Biotic reactions are known to be important in some circumstances and should be considered to fully simulate leachability. Both inorganic and organic constituents frequently undergo biological transformations within a source matrix. These transformations can directly change the chemical environment and composition of the leachate, and contribute to other secondary effects such as changing the nature of the leaching fluids and the setting within which leaching occurs.

The effect of biotransformation has been considered in some instances. The EP, the TCLP and other tests use an organic acid in an attempt to simulate codisposal with degradable materials. The oily waste extraction procedure requires extraction of oil from the solids prior to leaching, because biodegradation in nature will remove the oily film allowing more intimate contact with the leaching fluid.

It is often difficult to reproduce or simulate in batch extraction procedures, biotransformations which occur in field situations, in part because the temporal and spatial considerations for each are so different. Batch extractions are designed to evaluate equilibrium processes, while biotransformations are rate-limited. However, biotransformation studies are not inherently incompatible with column or dynamic leaching tests, and as such should be incorporated in those cases where they could be important. In attempting to integrate the assessment of biotransformation phenomena into a leaching test, it is critical to consider rate limitations in choosing the test's duration. The effects of biotransformation should be considered in interpreting or applying leachability results in cases where it can occur.

3) A consistent, replicable and easily applied , physical, hydrologic and geochemical representation should be developed for the waste management scenario of concern.

Central to devising leaching tests and models is the development of a sound conceptual framework of the physical system which is to be simulated. This framework requires proper and relevant identification of the precipitation-dissolution reactions by systematically examining the fluid and waste characteristics as well as the intrinsic chemical behavior of the constituents. This includes the equilibrium or steady state conditions as well as the reaction rate representing the dynamics of the leaching process. Reaction rate is an important, yet poorly understood, factor.

The complexities of fluid-solid waste interaction dynamics can occur in "real world" field conditions in which fluid parameters can change spatially and temporally with corresponding shifts in constituent release behavior. A constituent may initially occur in a highly soluble form, but may subsequently be transformed to highly insoluble precipitates, thereby rendering it immobile. Similarly, a constituent may be leached at a greater rate due to the very acidic or very alkaline pH of the leaching fluid. Dissolution of the protective matrix material may increase the potential for transport of the leaching fluid and the release of contaminants.

The Subcommittee believes that rate-limiting chemical and microbial reactions often play a pivotal role in governing leaching rate and contaminant fate. Consequently, situations can occur in which equilibrium concepts may not apply to some (and probably even to the majority) of the contaminant release (and transport) scenarios. It is expected that, in numerous instances, equilibrium-based projections of leachate levels can only provide an asymptotic (e.g., upper or lower limit) estimate of leachability that is not experienced at actual disposal sites during the management period of interest. In addition, hydrologic conditions and their spatial and temporal variations can impact on rates of dissolution and precipitation, mass transfer, and disequilibria. These effects and their impacts are not well understood, despite their important contributions to leaching of constituents to the environment. Despite these limitations, determinations of hazard for various contaminant release (and transport) scenarios are a necessity in order to accommodate the realities of statutory requirements and the attendant regulatory requirements.

If the intent is to match a test to an environmental situation with respect to contact time, a distinction could be made between situations where the waste is contained within a lined landfill (long contact time), or where the waste is underlain by a very porous medium or is in a flowing surface water (short contact time). Likewise, the leaching liquid-to-solid ratio at a waste management site is functionally (dynamically) related to rainfall, infiltration rates, the presence or absence of a cap over the waste, the quantity of waste, and other site-specific factors. Exceptions do occur based on site-specific factors. For example, if porous media have been plugged, this would increase contact time. Because of plugging phenomena, significant retention of waste leachate has been observed in some municipal landfills (such as in the Long Island, New York area), despite the fact that they are unlined and underlain by a very porous medium (sandy soil).

Explicit selection of leachate tests to best match repeated or continual leaching may require a determination of whether the particular management scenario involves wastes in a lined and/or capped landfill, or in more open systems in which greater contact exists with the surrounding environment. In the former case, the leachate may only be drained from the waste once. In the latter case, multiple leaching and contact times can reasonably be expected to occur. In most cases, multiple leaching can probably be expected, although contact times, liquid-to-solid ratios, pH and other environmental factors may vary, not only for different scenarios, but also for successive leaching events in a given environmental setting. This variability can be difficult to predict and simulate.

The nature and influence of physical dimensions (e.g., particle size and shape) of the waste matrix is difficult to predict for test development purposes. As a general principle, accuracy and reliability should be improved if the waste is leached in the form that is present in the environment, if it can be expected and demonstrated that the form of the waste will remain relatively unchanged with time. In other words, waste matrix dimensions should simulate what is expected in the environment over the time period of concern. It also follows that the dimensions range in test samples should reflect that of the wastes of concern.

A noteworthy issue is that some wastes in the environment clearly have dimensions which are too large to be examined with a particular laboratory test apparatus. Depending on accommodations to particular requirements of the test apparatus, this may or may not be a serious problem. If only a modest size reduction is required, such as reduction of a football-sized object to an average of one inch diameter, this is likely not to be a serious problem with respect to the development of leachability information, because the surface to volume perturbation is much less severe than had the requirement been to reduce the football-sized mass to milled wastes of a millimeter or less size range. The surface-to-volume ratio between large particles and those of an inch or so in size is not greatly different. However, diffusion limitations are intimately related to grain size and matrix uniformity, and the time scale is proportional to the square of the length scale. Size reduction may also cause changes in surface chemistry, redox conditions and availability of reaction sites.

One practical way to limit the size problem in batch tests is to mill or crumble wastes which do not have strengths appreciable enough to survive in the environment. Accurate predictions of leaching potential from wastes with intermediate strength may be better handled by subjecting them to sequential leaching accompanied by sequential particle size reduction. At the other extreme, exceptionally durable materials are best handled by leaching in an "as is" condition. Column tests, provided that channel effects are minimized or eliminated, are more amenable to testing wastes "as is" with respect to waste matrix size than are batch tests. Secondary tests which evaluate strength in waste management environments include, for example, the Toxicity Characteristic (TC) structural integrity test, unconfined compressive strength, freeze-thaw (ASTM Method 4843-38) and wet-dry (ASTM D4842-89) tests. Most batch leachate tests require wastes to be tumbled. It has been shown that if wastes are tumbled "as is", those which are not strong enough to survive in the environment will, in fact, break up during tumbling, while only strong materials will survive and remain intact (Bone et al, "Modification of the TCLP Procedure to Accommodate Monolithic Wastes," Fifth Annual Waste Testing and Quality Assurance Symposium, July 24-28, 1989). Additional testing may be necessary to determine whether the stabilized waste will remain a monolith under varying environmental conditions. Thus it is generally best to limit sample size reduction even in batch tests.

4) Leach test conditions (stresses) appropriate to the situations being evaluated should be used for assessing long-term contaminant release potential.

The best way to estimate the extent of contaminant release from a waste matrix of interest is to have a test that reflects realistic field conditions (Table 3, page <u>27</u>). However, the regulatory and statutory framework for decision makers often seems to require that estimates be made for the maximum potential for contaminant release in a specific scenario (Table 2, page <u>25</u>). This involves testing under extreme conditions or stresses, employing physical parameters such as fine particle size, temperature and pH set at high contaminant solubility, high ratio of leaching fluid to sample, high degree of mixing, and long fluid/particle contact time. But, while it may seem necessary from a regulatory and compliance perspective to use maximums in leach tests, every effort should be made to design realistic tests which simulate those actual worst case field leaching conditions that can be reasonably postulated to occur at some frequency in relevant waste management conditions.

In order to adequately characterize any particular field scenario for leach tests, the relevant environmental conditions postulated, and the degree to which they should be applied to samples undergoing contaminant release testing, should be carefully established and should take into consideration the nature of the regulatory decisions that are required. Moreover, any extrapolation of a set of conditions or stresses appropriate for one purpose should not be applied for other applications without reasonable verification of relevance. Extrapolation of tests designed for one purpose to another purpose should be scientifically defensible. A suggested approach to development of an array of leach tests follows:

a) First, identify the set of regulatory decisions that will be made with the test results.

The decision set could include (but is not limited to): (1) a decision whether or not a waste should be classified as hazardous; (2) the extent of leaching from a large volume waste in order to determine suitability for waste utilization or alternative management with or without restriction; (3) a determination of release potential to support an estimate of risk to human health or the environment; (4) a determination of solidification/stabilization effectiveness to provide a basis for a containment design; and, (5) selection of containment, treatment or remediation technologies.

b) Convene a panel of individuals that represent a cross-section of the regulatory community, the regulated community, academia, and environmental/public interest groups for the purpose of defining the array of conditions for each type of test.

Inputs should be sought from the broad technical (expert) community, for example, ASTM Committee D-34 on Waste Management and other technically credible groups of scientists, engineers and practitioners in the field. Consideration should be given to obvious stress factors such as: the appropriateness of sample size reduction, leaching fluid pH and buffering capacity, leaching temperature, waste-to-leaching fluid ratio, number and sequence of leaching steps, contact time, agitation mode, biological action, and exposure to freeze/thaw as well as wet/dry cycles.

c) Develop a hierarchial framework for reasonable stresses.

The set of possible stresses can be ranked from moderate to severe, and identified with appropriate regulatory decisions, depending on the conditions to which they are applied and the importance of the decisions.

Using the above rationale, as the need for a new decision is identified, its placement within and relevance to the decision-making framework of prescribed stresses (and extant leach tests) should be clear. While some procedures must be developed to make decisions in direct compliance with regulations, and require either site-by-site or type of application assessments, this recommended exercise could help to avoid the inappropriate application of a leach test or related test that has been developed for another purpose.

5) Laboratory leach tests should be field-validated, and release test accuracy and precision established before tests are broadly applied.

Numerous tests have been developed by the EPA, ASTM and others in order to estimate contaminant release and subsequent transport through soil matrices (Table 1, page <u>20</u> and Appendix C, page <u>35</u>). Some of the test methods have been subjected to extensive precision studies involving multiple laboratory samples and analysis, while other tests have clearly only been subjected to minimal or very limited evaluation, as in single laboratory precision studies. Furthermore, the accuracy of leaching test results has not been, for the most part, subjected to field verification. Anecdotal evidence suggests that the accuracy and reliability of laboratory test results for field application are questionable, primarily due to the simplifications or approximations utilized. In principle, the accuracy and precision of contaminant release predictions can be improved by matching the controllable test variables more closely to the environmental conditions that actually are encountered under field conditions. But it is questionable whether many leaching tests are adequately predictive of some reasonable worst case scenarios.

The number and types of analytes for which the tests have been evaluated and applied are likely to evolve continuously. Currently, all of the tests are designed for metals, semi-volatile, and non-volatile organics, and only a few are valid for volatile organics. Consequently, there are considerable data to determine the precision of the tests for metals. This is fortunate, since metals leachability is much more sensitive to factors which are difficult to control, such as pH, ionic strength and particle size. Thus, in view of current knowledge about metals leachability, much can be inferred about the fundamental processes involved in leaching of inorganic constituents from wastes.

As was suggested in the SAB EEC Leachability Workshop and technical briefing of May 9, 1990, review of the reliability and precision of metals leachability test results leads the Subcommittee to conclude that test precision is probably satisfactory, particularly in comparison to the reliability of test methods and variables associated with other factors which are used in conjunction with leachability to arrive at environmental risk assessments. Although the precision of any test used for regulatory decisions or environmental risk assessments should always be evaluated, test accuracy is more important than test precision.

The state of scientific capability for leaching test interpretation indicates that, in order to provide a realistic estimate of the leachability of a specific waste in a given environment, site-specific conditions must be fully considered. Consideration must be given to all factors that have the potential to impact leachability in either a positive or a negative fashion. For example, cosolvent effects can greatly facilitate the movement of contaminants out of the waste matrix, while biological activity can increase or decrease the release of contaminants as well as transform contaminants prior to their release into the environment.

Therefore, the Subcommittee recommends that, through the Office of Research and Development, EPA carry out a comprehensive "field validation" of leaching tests and establish laboratory accuracy and precision. The results should then be factored into guidance for the improvement of leaching tests.

6. More and improved leach models should be developed and used to complement laboratory tests.

Unlike the advances in models for transport and fate predictions, development of mathematical models to predict contaminant leaching is in its infancy. Only a small number of "leachate generation" models are proposed (e.g., HELP, FOWL^{TM}, UNIFAC), and to date these have had limited use.

While various laboratory tests can, in principle, be used to physically "model" a contaminant release scenario, more and improved "mathematical" models for leaching predictions should be developed and employed to complement laboratory tests.

Simple equilibrium (or as warranted, more comprehensive dynamic) models could be utilized to analyze data obtained from various leaching tests. These investigations could then be used to evaluate the applicability of such models as a leach test adjunct, or in more direct application, as an approach to estimating field leachability.

Contaminant release and transport models currently play an important role in the Agency's regulatory decision-making process. For example, the HELP model is used in the delisting regulation to project hydraulic flux through landfills. Further, the HELP model, in conjunction with the EPACML, is used to predict the dilution attenuation of contaminants from the bottom of a landfill to the nearest well. This and other models hold the promise of significant utility if: (1) they are sufficiently comprehensive and reliable for predicting the transport and fate of contaminants of concern; and (2) the data base necessary (including leachate composition) for model use is adequate and reliable. These criteria limit the conditions under which a model can be applied.

Potential pitfalls in the use of models should be examined prior to their application, to ensure that their results are reliable (Refer to the SAB Resolution on Use of Mathematical Models by EPA for Regulatory Assessment and Decision-Making (EPA-SAB-EEC-89-012), January 1989). Generally, such a review can proceed consistent with principles outlined in prior SAB deliberations on the generic use of models. Examples of concern to be addressed include: Agency over-reliance on models to the exclusion of the acquisition of needed data; the extent to which models are based on a fundamental representation of the relevant physical, chemical and biological processes that can affect environmental systems; the extent to which models have been validated with laboratory and field data; the analysis of sensitivity and uncertainty impacts on models and model predictions; and, the need to ensure adequate peer review of model development and utilization. In circumstances where laboratory and field data fail to confirm the adequacy of a model, it is inappropriate to use the model for decision making until improvements of an acceptable nature can be implemented.

Laboratory and field tests should be utilized to establish the conditions under which model simulations can be used to extrapolate laboratory and field data. A model should not be used to predict leachability or transport in scenarios that are outside the scope of the model applicability.

The sensitivity of a model to specific input data parameters should be established; this indicates the level of effort needed in the determination of the parameters for model evaluation. Pertinent questions include: How accurate should the input data be? Can input data be estimated by analogy rather than obtained from actual field measurements? Following these judgments, an appropriate data base can be developed for a model input.

Analysis should attempt to identify whether a different outcome might have been realized had more representative data been available, i.e., the expected model outcomes associated with varying degrees of data uncertainty should be established. Consistent with input data requirements, a model can then be used to predict leachability behavior in a specified field scenario.

7) To facilitate the evaluation of risk implications of environmental releases, the Agency should coordinate the development of leach tests and the development of models in which the release terms are used.

Leaching tests characterize the "source terms" for transport and fate models. Yet almost all transport and fate models assume that leachates are of constant concentration and of infinite duration and quantity. In reality, source terms (leachates) are a function of time, space, waste properties, and leaching fluid characteristics.

Numerous models presently are available to describe the transport of chemicals through porous material, including both the saturated and unsaturated zones. The hydrologic or fluid flow models (such as EPACML, HELP) could be improved to consider the chemistry and microbiology of contaminant release within the source waste matrix. The resulting leaching predictions would then be dynamically included in the transport analysis. The Subcommittee recommends that models used by the Agency be modified to couple source leaching masses with the transport and fate predictions. Such linked models would more accurately and precisely predict environmental concentrations to quantitatively evaluate risk implications, albeit at the cost of greater computational and data collection effort.

8) The Agency should establish an inter-office, inter-disciplinary task group, including ORD to help implement these recommendations and devise an Agency-wide protocol for evaluating release scenarios, tests, procedures, and their applications. The task group should also be charged with recommending what the appropriate focal point(s), responsibilities, and organizational, budgetary and communication links should be within the Agency for the most effective, continued and ongoing support and pursuit of

the research, development and utilization of methods and procedures.

The Subcommittee's discussions on Agency "needs" with the various program offices pointed out that a variety of applications and regulatory decisions depend on appropriate "release" tests and waste matrix transport and fate analyses (Table 2, page 25 and Appendix C, page 35). Therefore, it is recommended that an inter-office, inter-disciplinary task group be established to aggressively formulate implementation plans for the development of scientifically defensible leaching tests and models for the many contaminants and applications. This task group should include experts in the field of hydrology, soil science, analytical chemistry, environmental chemistry and biology, mathematical modeling and environmental engineering.

9) Core research on contaminant release and transport within the waste matrix is needed.

Consonant with the underlying concept of EPA's core research initiative and its intent to provide and sustain knowledge and expertise responsive to both current and future risks to human health and the environment, it is apparent from the preceding discussions that issues associated with leachability, and specifically methods to adequately measure and predict leaching from an assortment of waste matrices, are and should remain a priority focus.

Unfortunately, consensus with respect to the use of leachability testing protocols has yet to be attained. It appears that methods currently advocated neither fully satisfy short-term or long-term needs, nor do they withstand the rigors of scientific scrutiny to an extent that scientifically supportable management decisions can be made.

Therefore, the present state-of-knowledge concerning leaching phenomena under a broad range of waste management scenarios of regulatory and scientific interest should be fully analyzed and reported. Based on the outcome of this task, an integrated, active program of research, including exploration of potential and actual risks associated with leaching of constituents, should be developed.

The core research program regarding leachability should embrace, to the maximum extent feasible, all underlying issues pertinent to leachability. This should include, but not be limited to the following: basic mechanisms, potential test procedures, analytical methods, predictive model development, performance standards, and regulatory initiatives. Accordingly, a complementary understanding of the scientific and operational issues of various waste management options, as well as the intricacies of the associated environmental settings, is required. For instance, a possible approach may be to develop a waste management matrix which defines both current and potential future treatment, storage, use or disposal practices and associated environmental circumstances, and then develop companion testing protocols to simulate each situation. These tests should consider the operational phase as well as the pre-installation and post-closure periods.

Such an approach as recommended above should provide better correspondence between the results of testing protocols intended to simulate actual conditions under both short-term and long-term conditions. Whether these objectives can be accomplished with laboratory, pilot or field-scale simulations would be part of the challenge of the core research initiative. However, it could be anticipated that both short-term or accelerated screening and long-term field-scale simulations may need to be developed as an essential adjunct to each selected waste management alternative. The ultimate goal would be to provide operational as well as regulatory (and remedial) control, thereby enhancing the potential for more meaningful assessments of environmental and health risks.

TABLE 1 - EXTRACTION TESTS

I. STATIC TESTS (LEACHING FLUID NOT RENEWED)

A. AGITATED EXTRACTION TESTS

TEST METHOD	LEACHING FLUID	LIQUID:SOLID RATIO	MAXIMUM PARTICLE SIZE	NUMBER OF EXTRACTIONS	TIME OF EXTRACTIONS
TCLP (1311)	ACETIC ACID 0.1 N ACETIC ACID SOLUTION, pH 2.9, FOR ALKALINE WASTES 0.1 N SODIUM ACETATE BUFFER SOLUTION, pH 5.0, FOR NON-ALKALINE WASTES	20:1	9.5 mm	1	18 HOURS
EP TOX (1310)	0.5 N ACETIC ACID (pH=5.0)	16:1 DURING EXTRACTION 20:1 FINAL DILUTION	9.5 mm	1	24 HOURS
ASTM D3987-85	ASTM TYPE IV REAGENT WATER	20:1	AS IN ENVIRONMENT	1	18 HOURS
CALIFORNIA WET	0.2 M SODIUM CITRATE (pH=5.0)	10:1	2.0 mm	1	48 HOURS
LEACHATE EXTRACTION PROCEDURE (MOE, ONTARIO)	ACETIC ACID 2 MEQ/G	20:1	AS IN ENVIRONMENT	1	24 HOURS
QUEBEC R.S.Q (MOE, QUEBEC)	INORGANIC 0.02 MEQ/G ORGANIC DISTILLED WATER	10:1	GROUND	1	24 HOURS
FRENCH LEACH TEST (AFNOR, FRANCE)	DI WATER	10:1	9.5 mm	1	16 HOURS
EQUILIBRIUM EXTRACTION (ENVIRONMENT CANADA)	DISTILLED WATER	4:1	GROUND	1	7 DAYS
MULTIPLE BATCH LEACHING PROCEDURE (ENVIRONMENT CANADA)	ACETIC ACID BUFFER, pH 4.5	4:1 OR 2:1	9.5 mm	VARIABLE	24 HOURS

TABLE 1 - EXTRACTION TESTS (Continued)

TEST METHOD	LEACHING FLUID	LIQUID:SOLID RATIO	MAXIMUM PARTICLE SIZE	NUMBER OF EXTRACTIONS	TIME OF EXTRACTIONS
MATERIAL CHARACTERIZATION CENTRE-4 (MATERIAL CHARACTERIZATION CENTRE)	CHOICE	10:1	2 FRACTIONS 74 - 149 mm 150 - 425 mm	1	20 DAYS TO TO YEARS
OILY WASTE (1330)	SOXLET WITH THF AND TOLUENE EP ON REMAINING SOLIDS	100G:300ML 20:1	9.5 mm	3	24 HOURS (EP)
SYNTHETIC PRECIPITATION LEACHING PROCEDURE (1312)	VARIABLE	20:1	9.5 mm	1	18 HOURS
EQUILIBRIUM LEACH TEST	DISTILLED WATER	4:1	150 μm	1	7 DAYS

B. NON-AGITATED EXTRACTION TESTS

TEST METHOD	LEACHING FLUID	LIQUID:SOLID RATIO	MAXIMUM PARTICLE SIZE	NUMBER OF EXTRACTIONS	TIME OF EXTRACTIONS
STATIC LEACH TEST METHOD (MATERIAL CHARACTERISTIC CENTRE-1)	CAN BE SITE SPECIFIC	VOL/SURFACE 10μm	$40 mm^2$ SURFACE AREA	1	> 7 DAYS
HIGH TEMPERATURE STATIC LEACH TEST METHOD (MATERIAL CHARACTERIZATION CENTRE-2)	SAME AS ABOVE BUT AT 100°C	VOL/SURFACE 10μm	$40 mm^2$ SURFACE AREA	1	> 7 DAYS

C. SEQUENTIAL CHEMICAL EXTRACTION TESTS

TEST METHOD	LEACHING FLUID	LIQUID:SOLID RATIO	MAXIMUM PARTICLE SIZE	NUMBER OF EXTRACTIONS	TIME OF EXTRACTIONS
SEQUENTIAL EXTRACTION TESTS	0.04 M ACETIC ACID	50:1	9.5 mm	15	24 HOURS PER EXTRACTION

TABLE 1 - EXTRACTION TESTS (Continued)

D. CONCENTRATION BUILD-UP TEST

TEST METHOD	LEACHING FLUID	LIQUID:SOLID RATIO	MAXIMUM PARTICLE SIZE	NUMBER OF EXTRACTIONS	TIME OF EXTRACTIONS
SEQUENTIAL CHEMICAL EXTRACTION	FIVE LEACHING SOLUTIONS INCREASING ACIDITY	VARIES FROM 16.1 TO 40.1	150 μm	5	VARIES FROM 2 TO 24 HOURS
STANDARD LEACH TEST, PROCEDURE C (UNIVERSITY OF WISCONSIN)	DI WATER SYN LANDFILL LEACHATE	10:1, 5:1 7.5:1	AS IN ENVIRONMENT	3	3 OR 14 DAYS

II. DYNAMIC TESTS (LEACHING FLUID RENEWED)

A. SERIAL BATCH (PARTICLE)

TEST METHOD	LEACHING FLUID	LIQUID:SOLID RATIO	MAXIMUM PARTICLE SIZE	NUMBER OF EXTRACTIONS	TIME OF EXTRACTIONS
MULTIPLE EXTRACTION PROCEDURE (1320)	SAME AS EP TOX, THEN WITH SYNTHETIC ACID RAIN (SULFURIC ACID: NITRIC ACID IN 60:40% MIXTURE)	20:1	9.5 mm	9 (OR MORE)	24 HOURS PER EXTRACTION
MWEP (MONOFILL WASTE EXTRACTION PROCEDURE)	DISTILLED/DEIONIZED WATER OR OTHER FOR SPECIFIC SITE	10:1 PER EXTRACTION	9.5 mm OR MONOLITH	4	18 HOURS PER EXTRACTION
GRADED SERIAL BATCH (U.S. ARMY)	DISTILLED WATER	INCREASES FROM 2:1 TO 96:1	N/A	>7	UNTIL STEADY STATE
SEQUENTIAL BATCH ASTM D4793-88	TYPE IV REAGANT WATER	20:1	AS IN ENVIRONMENT	10	18 HOURS
WASTE RESEARCH UNIT LEACH TEST (HARWELL LAB-ORATORY, UK)	ACETIC ACID BUFFERED pH=5	1 BED VOL 5 ELUTIONS 10 BED VOL >6 ELUTIONS	CRUSHING	>11	2 TO 80 HOURS
STANDARD LEACHING TEST: CASCADE TEST SOSUV, NETHERLANDS	DISTILLED WATER HNO_3 pH 4.0	20:1	CRUSHING	5	23 HOURS

TABLE 1 - EXTRACTION TESTS (Continued)

B. FLOW AROUND TESTS

TEST METHOD	LEACHING FLUID	LIQUID:SOLID RATIO	MAXIMUM PARTICLE SIZE	NUMBER OF EXTRACTIONS	TIME OF EXTRACTIONS
IAEA DYNAMIC LEACH TEST (INTERNATIONAL ATOMIC ENERGY AGENCY)	DI WATER/SITE WATER	N/A	ONE FACE PREPARED	>19	>6 MONTHS
ISO LEACH TEST (INTERNATIONAL STANDARDS ORGANI-ZATION)	DI WATER/SITE WATER	N/A	SURFACE POLISHING	>10	>100 DAYS
ANSI/ANS 16.1 (AMERICAN NATIONAL STANDARDS INSTITUTE/ AMERICAN NUCLEAR SOCIETY)	DI WATER	N/A	SURFACE WASHING	11	90 DAYS
DLT	DI WATER	N/A	SURFACE WASHING	18	196 DAYS

C. FLOW THROUGH TESTS

TEST METHOD	LEACHING FLUID	LIQUID:SOLID RATIO	MAXIMUM PARTICLE SIZE	NUMBER OF EXTRACTIONS	TIME OF EXTRACTIONS
STANDARD LEACHING TEST: COLUMN TEST (SOSUV, THE NETHERLANDS)	DI WATER HNO_3 pH=4	10:1	AS IN ENVIRONMENT	7	20 DAYS
COLUMN ASTM D4874-89	TYPE IV REAGENT WATER	ONE VOID VOLUME	AS IN ENVIRONMENT	1	24 HOURS

TABLE 1 - EXTRACTION TESTS (Continued)

III. OTHER TESTS

TEST METHOD	LEACHING FLUID	LIQUID:SOLID RATIO	MAXIMUM PARTICLE SIZE	NUMBER OF EXTRACTIONS	TIME OF EXTRACTIONS
MCC-5S SOXHLET TEST (MATERIAL CHARACTER-ISTIC CENTER)	DI/SITE WATER	100:1	CUT AND WASHED	1	0.2 ML/MIN
ACID NEUTRALIZATION CAPACITY	HNO_3 SOLUTIONS OF INCREASING STRENGTH	3:1	150 µm	1	48 HOURS PER EXTRACTION

REFERENCES:

1. Compendium of Waste Leading Tests, Waste Water Technology Centre, Environment Canada, Final Draft May 27, 1989
2. Private discussions with Gail Hansen, Office of Solid Waste, U.S. EPA

TABLE 2 - TEST REQUIREMENTS, USES OF TESTS, AND PROGRAMATIC NEEDS FOR LEACHABILITY TESTS BY THE AGENCY AS PERCEIVED BY THE SCIENCE ADVISORY BOARD's ENVIRONMENTAL ENGINEERING COMMITTEE

	PROGRAM OFFICE *					
TEST REQUIREMENTS	**SF**	**SC**	**OSW**	**OTS**	**RSKERL**	**OMMQA**
Simple method	O	X	X	O	O	X
Field Analog	X	X	O		O	O
Model Source Term	X	O	X	O	X	X
Predict Leaching	X		X	O	X	X
Method Validation	X		X	O	X	X
TIE Compatible		X		O		
Surface Water Interface	X	X	O		O	O
Mismanagement Predictor	X	X	X		X	X
Waste Classification	X	X	X	X	X	X
"No Reasonable Risk" Determination				X	O	O
USES OF TESTS						
Demonstrate Federal/ State Compliance	X	X	X	X	O	X
Simulate Risk	X	X	X	X	X	X
Set Standards	X	O	X	X	O	O
Compare Waste Management Strategies	X	O	X	X	O	X
Compliance/ Clean-Up Goals	X	O	O	O	O	X
Examine "Worst Case"	X		X	O	X	X
Apply to Human Health	O	X	O	O	O	O
Identify Toxicants	O	X	X	X	X	X
New Product Information				X		O
Establish "Equivalency" To Thermal Destruction				X		O
Evaluate Lined and Unlined Units	X		X	O	O	O

TABLE 2 - (Continued)

PROGRAMATIC NEEDS FOR TESTS	SF	SC	OSW	OTS	RSKERL	OMMQA
	PROGRAM OFFICE *					
Flexibility	X	X	O		O	O
Multiple Tests	X	X	O		X	X
Standardized Protocols		X	X	O	O	O
Compliance	X	X	X	X	X	X
Remedial Design	X	O	O	O	X	O
Biological Response	O	X	O	O	O	O
Matrix Data	X	X	X	O	X	X
EP/TCLP	X		X	O	X	O
Acid Rain Leaching	O	O	X		X	O
Multiple Extraction	O	O	X	X	X	X
Oily Waste Extract	O	O	X	X	X	X
Equivalent Tests				X		O
Non-Destructive Tests	O	O	O		O	O

* SF = Superfund Program, US EPA
SC = Office of Water, Sediment Critria Program, US EPA
OSW = Office of Solid Waste, US EPA
OTS = Office of Toxic Substances, US EPA
RSKERL = R.S. Kerr Environmental Research Lab, US EPA
OMMQA = ORD/Office of Modeling, Monitoring, and Quality Assurance, US EPA
X = Yes, a Blank Signifies No
O = Sometimes or Occasionally

TABLE 3 - SCIENTIFIC CONSIDERATIONS IN DESIGN AND INTERPRETATION OF LEACHABILITY TESTS

PROPERTIES/CHARACTERISTICS	IMPORTANCE AND TEST RAMIFICATIONS
1. Source Matrix Properties	Matrix properties affect availability and accessibility of contaminants.
Chemical composition (functional groups, carbon content, etc.)	Relates to containment and leaching environment.
Morphological structure (amorphous vs. crystalline)	Affects access and containment.
Surface area (surface-to-volume ratio)	Determines interface for sorption; can affect pH.
Surface physics (e.g., charge, tension)	Controls access and flow in the pores matrix.
Matrix heterogeneity	Creates morphological and chemical differences.
Pore structure (volume, distribution)	Constricts flow, retains gas, serves as "small" reactor.
Pore liquid volume (degree of saturation)	Contributes to effective leachate volume.
Pore liquid composition	Modifies leachate composition.
Permeability	Affects flow regime and residence time.
Ease of saturation (time, pressure required)	Leachant/waste interface may be limited by the rate and extent of saturation.
Pooling (micro- and macro-reservoirs, field capacity)	Extracting fluid ("leachant") and leachate retention; provides *in situ* reaction opportunity.
Biodegradability	Matrix can change properties due to biodegradaton.
Toxicity	May limit biodegradation of the contaminants or matrix property changes.

TABLE 3 (continued)

PROPERTIES/CHARACTERISTICS	IMPORTANCE AND TEST RAMIFICATIONS
Buffer capacity	Availability of buffer capacity affects leachability and diffusion, and regulates efficiency and nature of biodegradation.
2. Contaminant Properties	Leachability is a function of the nature of the contaminants.
Chemical composition	Different chemicals or the same contaminant in a different physical or chemical form exhibit distinct differences in leachability.
Concentration	Concentration gradients affect leaching rate and equilibria.
Toxicity	Reduces efficiency of concurrent biotransformation.
Biodegradability	Compound structure and environmental conditions affect biodegradability.
Heterogeneity	Affects containment and availability for reaction and/or leaching.
Diffusivity	Determines transport via diffusion.
Solubility	May affect mass transport and limit removal and/or reaction.
Volatility (boiling point, Henry's constant)	Controls liquid/vapor phase transport and loss of contaminants during leaching and analysis.
3. Leachant Properties	Leachant properties control solubilization/dissolution and mass transport processes.
Initial chemical composition	Could contain contaminants, may be aggressive, may change as the leaching process proceeds.
Aqueous/non-aqueous	Normally water (distilled, tap, or site) as modified by test protocol.

TABLE 3 (continued)

PROPERTIES/CHARACTERISTICS	IMPORTANCE AND TEST RAMIFICATIONS
Hydrophobic-hydrophilic nature **	Surfactants or hydrophobic solvents could enhance leaching.
Gas (oxygen, carbon dioxide content, etc.)	Affects pH and nature of biological, physical and chemical interactions.
Density	Contributes to hydraulic gradient effects and hydraulic conductivity.
Buffer capacity	Controls pH change.
Viscosity	Affects flow regime, saturation, and hydraulic conductivity.
pH	May or may not control the leaching process.
4. Fluid Dynamics	Fluid dynamics in a given system dictate contact time and opportunity, which affect reaction extent and mass transfer. Fluid dynamics have important ramifications to the selection of leaching mode, e.g., continuous column, batch, sequential batch; equilibrium (intended to represent specific, worst case scenarios), non-equilibrium; dynamic (mixed), static.
Flow gradient	Affects transport of contaminants by dispersion, convection, and advection. Also affects mechanism of mass transport. Agitation may be used to generate a maximum gradient. Flow path could lead around or through the waste. Cracks or inter-connected pores would short-circuit flow.
Flow regime (laminar vs. turbulent)	Affects contaminant transport and gradient. Restricts the applicability of Darcy's Law.

** NOTE: This is also a contaminant characteristic which determines affinity to leach or to be bound in a matrix.

TABLE 3 (continued)

PROPERTIES/CHARACTERISTICS	IMPORTANCE AND TEST RAMIFICATIONS
Flow pattern (intermittent vs. continuous)	Could weather and/or disintegrate waste matrix. Impacts on the concentration gradient and transport.
5. System Properties	Operationally determined by the leachant/waste interaction.
Precipitation/dissolution/ reprecipitation	Potential removal/release process.
Solubilization (capacity, limits)	Ability to remove contaminants by dissolution.
Other chemical reaction and reversibility	May change contaminant behavior and/or structure.
Complexation	Affects transport, solubilization and possible surficial binding of metals and organometallic compounds.
Sorption/desorption	Contributes to the retention or removal of solutes.
Partitioning	Affects equilibrium opportunity and spatial and temporal distribution.
Cosolvency	Enhanced removal by solvent mixtures, affects distribution of solutes.
Common ion effect	Could delay the removal of contaminants associated with more than one anion.
Redox environment	Could affect opportunity for biological or chemical transformations and reactivity.
pH	Major influence on biological, physical and chemical transformation processes.
Temperature	Affects reaction rates, solubility, pore pressure, etc.
Mass transfer or equilibrium limitations	Need to determine which dominates.

TABLE 3 (continued)

PROPERTIES/CHARACTERISTICS	IMPORTANCE AND TEST RAMIFICATIONS
6. Temporal/Spatial Dependence	Temporal and spatial limitations may accelerate or retard leaching.
Contaminant recharge	Important element of tests involving site-specific simulations.
Aging dynamics	Physical and chemical properties may change in time.
Weathering effects (dissolution surface washing, wet/dry, freeze/thaw)	Long-term humidity and temperature changes affect matrix integrity.
Biodegradability	Aerobic and anaerobic transformation of and within the matrix.
Barometric fluctuation	Impact gradients, dispersion, and groundwater movement, and behavior of gases and volatiles.
Leachant volumes (contact time)	Major consideration when selecting the leachant/waste (or source matrix) ratios. Leachant/source-matrix interface over an extended period of time could result in the depletion of the contaminant or in the erosion of the matrix.
7. Monitoring methods	Method of monitoring could influence the test and their results.
Precision/accuracy (overall)	To be defined by the data quality objectives.
Environmental sampling, sample preservation/holding time (environmental samples and leachate test samples)	Affects results; plans and standards may be available.
Leaching test	Selected in accordance with objectives. Considers time, environmental conditions, and site specifity.
Leachate preservation/storage	Sample components change with time.

TABLE 3 (continued)

PROPERTIES/CHARACTERISTICS	IMPORTANCE AND TEST RAMIFICATIONS
Analytical (sample preparation and test method)	Reproducible, specific, and efficient methods are available. Analytical procedures need to be appended with appropriate protocols.
Testing schedule (time)	Could affect reproducibility, interpretation, and comparability of data.
8. Physical Modeling	
Comparability with scenario to be simulated	Similar in form and arrangement.
Congruence with scenario	Governs applicability of results.

APPENDIX A - BACKGROUND ON LEACHABILITY AS A SELF-INITIATED ACTIVITY OF THE SCIENCE ADVISORY BOARD

Over the past decade, the Environmental Engineering Committee (EEC) of the Science Advisory Board (SAB) has reviewed a number of EPA subjects and issues involving leachability phenomena either as a major or minor factor in the review. In these various reviews, the Committee has noted a number of problems and issues, relating to leachability phenomena that were common to a variety of programs, rules and Agency procedures. The Committee believed that these common problems and issues, would be best called to the Agency's attention through a general set of recommendations on leachability phenomena, rather than in the specific, individual reviews.

Believing that the scientific principles of contaminant leachability need broader understanding and exposition, the EEC has undertaken the initiative, with the concurrence of the Executive Committee, to conduct this self-initiated review to:

1) Consider the fundamental scientific principles that can reliably describe contaminant release/transport. In particular, to consider the controlling characteristics of the source, the leaching media and the importance of dynamic considerations; and

2) Suggest how the scientific principles can be applied to determine how a waste will leach when present in the environment, according to a prescribed scenario.

The Leachability Subcommittee (LS) was formed by the EEC. The group convened a project scoping and planning session in Houston, Texas on December 15-16, 1989, immediately following a Workshop related to this topic. The LS then followed this with a one-day session in EPA's Headquarters Office in Washington, D.C. on February 26, 1990, devoted to assessing the Agency's varied needs for leachability-related information. The day's activities and findings were then discussed with the full EEC on February 27, 1990. This was followed by a Workshop on Leachability on May 9, 1990 in Washington, D.C. The Workshop was conceived as a vehicle for distinguished scientists, engineers and practitioners in the field to focus on the scientific principles and issues relating to leachability phenomena. The Workshop was video taped, so that those unable to attend from EPA or any other interested parties could have the benefit of this exchange of information.

The Leachability Workshop assisted the LS of the SAB's EEC to better define the fundamental scientific principles that control leachability. Further, the workshop assisted the SAB and the attendees in ascertaining how leachability phenomena and tests can be applied on an appropriate and consistent basis to determine how a waste will leach when present under various scenarios in the environment.

APPENDIX B
LEACHABILITY WORKSHOP PROGRAM
May 9, 1990

Welcome and Administrative Remarks	Dr. C.H. Ward Mr. Richard A. Conway
Statement of Issues and Needs	Dr. Raymond C. Loehr
Test Methods: Descriptions, Capabilities, Organics-Inorganics	Dr. Pierre Côte'
Leaching of Stabilized Materials	Dr. Paul Bishop
Physical-Chemical Mechanisms: Concepts on Interactions of Solids-Liquids, Liquid-Liquid, Solids-Liquids-Gases	Dr. Marvin Dudas
Technical Problems and Challenges for Regulators and the Regulated	Mr. Robert L. Huddleston
Leaching Chemistry of Inorganics	Dr. John M. Zachara
Leaching Chemistry of Organics	Dr. P. Suresh Rao
Alternative Approaches to Laboratory Tests (Modeling)	Dr. Carl Enfield
Concluding Remarks	Dr. C.H. Ward Dr. Ishwar P. Murarka

CONVENERS AND SPEAKERS

Dr. C.H. Ward, Chairman, Leachability Subcommittee, Rice University, Houston, Texas

Dr. Ishwar P. Murarka, Vice-Chairman, Leachability Subcommittee, Electric Power Research Institute, Palo Alto, California

Mr. Richard A. Conway, Chairman, Environmental Engineering Committee, Union Carbide Corporation, South Charleston, West Virginia

Dr. Raymond C. Loehr, Chairman, Science Advisory Board, University of Texas, Austin, Texas

Dr. K. Jack Kooyoomjian, Designated Federal Official, US EPA, Science Advisory Board

Dr. Donald G. Barnes, Director, US EPA, Science Advisory Board

Mr. A. Robert Flaak, Assistant Staff Director, US EPA, Science Advisory Board

Dr. Pierre Côte', Zenon Environmental, Inc., Burlington, Ontario, Canada

Dr. Paul Bishop, University of Cincinnati, Cincinnati, Ohio

Dr. Marvin Dudas, The University of Alberta, Edmonton, Alberta, Canada

Mr. Robert L. Huddleston, Conoco, Inc., Ponca City, Oklahoma

Dr. John M. Zachara, Battelle Pacific Northwest Laboratories, Richland, Washington

Dr. P. Suresh Chandra Rao, University of Florida, Gainesville, Florida

Dr. Carl Enfield, R.S. Kerr Environmental Research Laboratory, Ada, Oklahoma

APPENDIX C - LEACHABILITY NEEDS, USES, TESTS, CONCERNS, AND ISSUES

C-1 - SUPERFUND REMEDIAL AND REMOVAL PROGRAMS

NEED FOR USE OF LEACHING TESTS

- Need to comply with Federal and State laws that are applicable, or relevant and appropriate (e.g., RCRA)
- Need to approximate real world conditions
- Need for methods which provide input to groundwater modeling
- Need for standardization of leaching methods (including K_d for specific applications and data uses
- Need for methods development for predicting long-term leaching potential
- Need for validation of leaching methods
- Leaching, extraction and other chemical test are typically needed to provide a variety of data on either untreated or solidification/stabilization (S/S)-treated wastes for the following purposes:
  - To identify principal threats which indicate mobility of contaminants (e.g., in untreated or S/S-treated waste) when they are in the environment (e.g., in contact with leaching medium and each other)
  - Determine compliance with regulations, such as CERCLA, RCRA (e.g., if land ban BDAT has been met)
- To show that reduction in mobility of the hazardous components has been achieved between untreated and treated wastes, or that treated waste is protective (i.e., that it meets National Contingency Plan expectations, such as passing a specific test, such as the TC test)
  - To assess the effectiveness of a technology (e.g., S/S technology)
  - To estimate source terms and/or boundary conditions for ground-water modeling
  - To look for "hot-spots," and in many cases, locate with model instead of acquiring (sometimes extensive) data

USES OF LEACHABILITY AND LEACH TESTS

- To demonstrate compliance with Federal and State laws (e.g., RCRA, TSCA, etc.)
- To model risk to:
  - Assess potential for groundwater and surface water contamination
  - Establish clean-up standards
- Selection of Remedy:
- To differentiate among various waste management regimes for modeling and assessing risk
  - In situ management/disposal (modeling)
  - Delisting
- To ensure that waste management alternatives address environmental concerns
- To predict long-term environmental behavior (e.g., such as for "mixed" waste, radioactive, RCRA hazardous waste, debris and/or large objects)
- To determine chemical characteristics of wastes
- To identify possible interference with treatment (e.g., immobilization)
- To evaluate treatment (e.g., treatment residuals) compliance with clean-up goals
- Input data to modeling, such as fluxes into saturated zone (e.g., ANSI 16.1)
- For organics, such as immoble constituents, low concentrations to examine:
  - "Worst case" leaching
  - Total waste extraction
  - Non-polar solvents for PCB's

TYPES OF DATA REQUIRED, SPECIAL CONCERNS, ISSUES AND CONSTRAINTS (e.g., variables that can affect test results.)

- Superfund allows flexibility in choice of Leachability test based on site specific conditions and needs

- National Contingency Plan (NCP) outlines program goals and expectations which drive the remedy selection process. Some of the expectations are:
  - EPA expects to use treatment to address principle threat wastes (e.g., highly toxic, mobile, etc.)
  - EPA expects to use engineering controls (e.g., containment) to address wastes which pose a relatively low long-term threat or where treatment is impracticable
  - EPA expects to return usable ground waters to their beneficial uses whenever practicable

- Parameters that can affect test results include:
  - Sample heterogeneity
  - Curing time
  - Liquid-to-solid ratio
  - Extraction time, number and frequency
  - Leaching medium

- Superfund is unique in that the program can use flexibility on a site-by-site and case-by-case technical basis for selection of remedy:
  - Additional goals in the NCP aim to treat waste that are the principal threat (e.g., highly mobile, toxic, etc.)
  - Probably will not excavate and treat non-mobile wastes which are not the principal threat
  - Generally, there is an expectation goal to reduce toxicity, mobility and volume of the waste by 90% to 99% (whether or not this presumption is valid)

- Superfund may use multiple tests. Various leach tests (e.g., 18 hours versus 90 days or more) are employed. There is a large variety, depending on the waste and the disposal scenario:
  - The more agreement and consensus on appropriateness of tests, the more important are the tests to the program (e.g., decisions in New Jersey and California should be consistent.)

- Superfund waste removal activities have more flexibility than remedial activities. However, the science and technical decisions must withstand scrutiny.

- For Superfund, RCRA protocols may not be appropriate because:
  - The Superfund application is a different purpose than for what the RCRA protocol was originally devised.
  - Lack of standardized protocols in Superfund
  - Many methods exist with a lot of variability
  - Technical uncertainty on making sense of the varied forms of data to make a decision.

TYPE OF TESTS

- Note that all treated wastes (not just solidified/stabilized (S/S) treated wastes) need to be evaluated to determine how protective they are in specific management scenarios

- While Superfund program must comply with Federal and State regulatory requirements (e.g., RCRA TCLP methodology), other tests may be utilized to approximate real world conditions. Single or multiple methods may apply to a site. Additional methods may include the following listed below:
  - Short-term extraction tests (hours to days)
  - Leaching tests (weeks to years)
  - Column Leach Test
  - EP (Method 1310) (Was used in the past, but is superseded by the TCLP)
  - TCLP (Method 1311)
  - TCLP with cage modification (This has never been promulgated and appears to have reproducibility problems)
  - California Waste Extraction Test (Cal WET)
  - Multiple Extraction Procedure (MEP)
  - Synthetic Acid Precipitation Leach Test
  - Monofilled Waste Extraction Procedure (Method 1312) (MWEP)
  - Materials Characterization Center Static Leach Test
  - American Nuclear Society Leach Test
  - Dynamic Leach Test (DLT)
  - Shake Extraction Test
  - Others

NEEDS FOR USE OF LEACHING OR OTHER TESTS

- Simple methods that can be simply used by field people for all types of sediment and water environments to address the toxicity of sediment:
  - Need for an in-the-field practical method where each method is not turned into a "research project"
  - The AET (Apparent Effects Threshold) method uses a preponderance of evidence approach
  - The AET method has no relevance to sediments that are exposed to leaching conditions
  - Addresses the toxicity of <u>in-place</u> sediments
- Methods to provide sediment criteria decisions to evaluate the following:
  - Most likely scenario
  - Methods to be applicable to human health, aquatic life or wildlife protection
  - Ability to generate numerical criteria for specific chemicals
- Toxicity Identification Evaluation (TIE) procedures to identify and quantify chemical components responsible for sediment toxicity, such as:
  - Techniques for the identification of toxic compounds in aqueous samples containing mixtures of chemicals
  - Interstitial water toxicity method TIE procedures are implemented in three phases to evaluate:
    - Pore water toxicity,
    - Identify the suggested toxicant, and
    - Confirm toxicant identification.

USES OF LEACHABILITY AND LEACH TESTS

- Sediment criteria decisions for:
  - Applicability of method to human health, aquatic life or wildlife protection
  - Predicting effects on different organisms
  - Suitability for in-place pollutant control
  - Suitability for source control
  - Suitability for disposal actions
  - Suitability for different sediment types
  - Suitability for different chemicals or classes
  - Ability to generate numerical criteria for specific chemicals
- Toxicity Identification Evaluation (TIE) potential uses:
  - Use of pore water as a fraction to assess sediment toxicity
  - In conjunction with TIE procedures, can provide data concerning specific compounds responsible for toxicity in contaminated sediments
  - Ability to identify specific toxicants responsible for acute toxicity in contaminated sediments

TYPES OF DATA REQUIRED, SPECIAL CONCERNS, ISSUES AND CONSTRAINTS (e.g., variables that can affect test results.)

- Types of data required:
  - Biological response data (either acute or chronic)
  - Choice of Test Organism
- Practical concerns of method choices:
  - Ease of use
  - Relative cost
  - Tendency to be conservative
  - Level of acceptance
  - Ability to be implemented by laboratories with available/typical equipment and handling facilities
  - Degree to which results lend themselves to the following:
    - Interpretation
    - Environmental applicability
    - Accuracy and precision
- Concern for leaching of hazardous substances or hazardous materials to food, plants, groundwater and sediment
- Concern for monofilling and impacts on groundwater:
  - There are differences in sorptive capacity (reductions) observed in monofill versus an increase in sorptive capacity in well-aerated soil (plow zone)
- Groundwater to surface water issues
- All current sediment criteria development efforts address the toxicity of <u>in-place</u> sediments. As a result, research activities have not focused on what happens to sediment-bound chemicals when exposed to leaching conditions:
  - Some research suggests that for non-ionic organic contaminants, the presence of organic carbon in leaching materials may be responsible for some binding of contaminants, as well as mobility
  - For metals, it is possible that the leaching conditions might provide for the release of significant levels of metals, because of the expected reduction of the acid volatile sulfide (AVS) content of many sediments
    - AVS binds up significant levels of metals and is lost when exposed to oxidizing conditions

TYPE OF TESTS

- Aeration tests
- Bioassays
- Equilibrium Partitioning Approach
- Solid phase extraction tests
- Graduated pH test
- Filtration tests
- Reversed phase, Solid Phase Extraction (SPE) tests
- Oxidant reduction test
- EDTA addition test (The EDTA - Ethylene diamine tetraacetic acid test)
- Hollow block with a semi-permeable membrane, which is inserted into the sediments

NEEDS FOR USE OF LEACHING TESTS:

- Statutory requirement of RCRA to look at reasonable worst-case mismanagement and maintenance scenarios to assess:
  - Landfill scenarios (sanitary and monofill)
  - Maintenance scenarios
  - "Mismanagement" scenarios
  - Acid leaching scenarios
  - Pump and treat systems
  - Effect of covers
  - Effect of Liners
- To characterize the leachate source term, such as:
  - Finite versus infinite source of waste
  - Effect on leachate quantity
  - Effect on leachate quality
- To determine if a waste is hazardous or non-hazardous. (Such determinations are built into RCRA.):
- To determine how a particular material needs to be managed:
  - Need a decision-making tool to evaluate leachability
  - Need to examine various scenarios and their validity

USES OF LEACHABILITY AND LEACH TESTS:

- To model and simulate risks
- To assess risks
- To direct regulatory decisions
- To come to grips with the complexities of leachability phenomena (i.e., the source term itself is very difficult and complex)
- To answer questions pertaining to what kind of contaminant levels are appropriate to be left in the soil or removal from the soil (e.g., clean closure)

TYPES OF DATA REQUIRED, SPECIAL CONCERNS, ISSUES AND CONSTRAINTS (That is, variables that can affect test results.):

- Factors affecting leachability include, but are not necessarily limited to the following:
  - Size of materials
  - Permeability of solid
  - Time dependency of leaching
  - Contact time (a crucial issue_
  - Type of contact (tumbling versus stirring)
  - Ratio of leaching fluid to waste (i.e., solubility versus mass-limited; also, infinite source versus finite source)
  - Changes in the waste itself (e.g., due to biodegradation, chemical changes, anaerobic versus aerobic, hydrology, and climate changes)
- Issue of scenarios where organics may be bound better under acid, rather than neutral or basic circumstances (Many industrial landfills are highly on the basic side)

TYPE OF TESTS

- EP (Extraction Procedure) (Method 1310)
- TCLP (Toxicity Characteristic Leaching Procedure) (Method 1311)
- TCLP with cage modification
- Acid rain leaching tests for large volume wastes (Method 1312)
- Multiple Extraction Procedures (MEP) for delisting
- Oily Waste Extraction Procedure (OWEP) for delisting

C-4 - OFFICE OF TOXIC SUBSTANCES

NEEDS FOR USE OF LEACHING TESTS

-TSCA is a "No Unreasonable Risk" Statute

- The only alternative technologies acceptable, for instance for PCB's, must demonstrate that they are equivalent to thermal destruction of PCB's (e.g., solidification of PCB's would cause a problem under these TSCA criteria.)

- TSCA is also a cost-benefit statute:
  - Possible use of waivers by EPA Regional Administrators
  - With this (cost-benefit) constraint, there could be a problem between what the Superfund and the Office of Toxic Substances programs says are "low" and/or acceptable concentrations
  - Need some tests to determine the long-term effectiveness of these problems

USES OF LEACHABILITY AND LEACH TESTS

- Particularly interested in leachability data, especially for new product information in the PMN (Pre-Manufacturing Notification) program for new and existing chemicals

- OTS is in need of information on leachability for establishing the equivalent comparison in a chemical waste landfill, which is the only non-destructive method that is authorized (that is not to say that treatment processes that are non-destructive would not be examined)

TYPES OF DATA REQUIRED, SPECIAL CONCERNS, ISSUES AND CONSTRAINTS (This is, variables that can affect test results.)

- Equivalency test data, for alternative technologies to thermal destruction

- Cost-benefit data on alternative technologies to incineration:
  - The Office of Toxic Substances is in need of information that examines the alternative technologies to incineration
  - The alternative technologies to incineration must demonstrate equivalency
    - Need to know what kind of leachability criteria would be needed to obtain a revised equivalent to incineration
    - Also, need to know what kind of laboratory testing should be required to give results equivalent to incineration

- R&D is needed to answer above.

TYPE OF TESTS

- Equivalency tests (as compared to the incineration alternative) need to be developed

- At present, disposal of waste in chemical waste landfill is the only non-destructive method that is authorized

- Other treatment processes that are non-destructive could be possible, but to date, no research has occurred to develop such non-destructive tests which demonstrate the equivalence to incineration

- Need some tests to look at the long-term effectiveness of these problems

NEEDS FOR USE OF LEACHING TESTS

- The RCRA statute requires development and use of Leachability data and tests

- Mission of the Lab. and the technical support center is to further understanding of subsurface media to:

  - Remediate contaminated vadose and saturated zones
  - Provide a technical support bridge between the Lab. and the EPA regional and state regulators

  - R.S. Kerr Lab. is primarily a user and not a developer of different Leaching test methods and alternative procedures:

  - EPA ORD, EPA OSW, ASTM, NRC and others develop leaching tests

USES OF LEACHABILITY AND LEACH TESTS

- To answer questions pertaining to what kind of contaminant levels are appropriate to be left in the soil, so that there will not be a problem later (i.e., so that leachate through the soil will be protective of groundwater). Hence, this leads to the following questions:

  - What kind of leaching test can be used to develop criteria for "safe levels?"
  - What site specific processes must be considered in the criteria development process?
  - What kind of vadose zone models should be used?

TYPES OF DATA REQUIRED, SPECIAL CONCERNS, ISSUES AND CONSTRAINTS (That is variables that can affect test results.)

- To develop a "family of procedures" and to determine when it is appropriate to use each procedure to answer site-specific questions

- Ability to get source term in model is a problem

- Need to act conservatively, particularly with organics, but need to use "common sense"

- There is considerable competition between different tests

- To date no evaluation has been made as to what, in fact, are the reasonable stresses, such as:

  - When to grind or not to grind a waste
  - When to apply acid and at what strength and duration

- Issues with appropriate tests for radionuclides and mixed wastes:

  - What kind of test will be applicable to low-level radioactive material?
  - Is EP Tox. or TCLP appropriate? Under what circumstances?

- There are no "standard" R&D leaching tests or migration potential evaluation protocols for Superfund on-site remedies

- For the combustion residue area, the following issues illustrate special concerns and constraints:

  - The ability to get the appropriate source term is usually a basic problem
  - The R&D program uses a lot of different procedures to develop a credible data base
  - In this context, ORD is primarily a user, and not a developer of methods for leaching tests
  - The R&D staff are using a lot of different procedures to develop a credible data base

TYPE OF TESTS

- EP (Method 1310)
- TCLP (Method 1311)

C-6 - R&D PERSPECTIVE OF THE OFFICE OF MODELING, MONITORING, AND QUALITY ASSURANCE, WASHINGTON, D.C.

USES OF LEACHING TESTS

- Determining regulatory status of waste
- Determining effectiveness of treatment processes which are designed to reduce Leachability
- Determining leachability of waste under different management scenarios

TYPES OF TESTS NEEDED (SCENARIOS TO BE MODELED)

- Sanitary Landfill co-disposal:
  - Lined unit
  - Unlined unit
- Monowaste disposal
- Dedicated, mixed waste unit
- Uncontrolled contaminated soil

USES OF TRANSPORT TESTS

- Predicting transport through media as input to fate and transport models (i.e., serve as the source term for the models)

TYPES OF TESTS NEEDED (ENVIRONMENTS TO BE MODELED)

- Vadose Zone:
  - Moist
  - Dry
- Saturated Zone:
  - Sandy
  - Clay
  - Loam
  - Calcarious
  - Acidic
- Effect of waste on Leachability/transport of material from other wastes

C-7 - CRITERIA AND OBJECTIVES OF LEACHING TESTS AND MODELING CONSIDERATIONS FOR PARTITIONING TESTS FROM THE PERSPECTIVE OF REGULATORS VERSUS INDUSTRY

INDUSTRY VIEW OF THE PERSPECTIVE OF THE REGULATORS

- Simplicity (e.g., simplicity of test protocol)
- Reproducibility
- Conservatism, if realism is not practical
- One/few tests to fit most wastes
- Use to delineate "non-hazardous" versus "hazardous" wastes (e.g., differentiating between wastes needing RCRA "C" standards management and wastes that only need "D" controls.)
  [NOTE: The above is in contrast to a large part of the Agency's response, particularly Superfund and the Kerr Lab.]

PERSPECTIVE OF INDUSTRY

- Simplicity only where appropriate,
- Reproducibility
- Realism in approximating site and waste specific conditions
- Test variations to account for waste differences
- Suitable for differentiating between different disposal conditions
- Use to define acceptable disposal conditions

TYPICAL CURRENT PRACTICES OF INDUSTRY IN LEACHATE TESTING

- Determine regulatory status of waste, such as hazardous waste e.g., Subtitle C which is subject to land ban), EP, TCLP and SPLP (e.g., Method 1312)
- Determine reasonable worst-case releases from waste residual oils, and contaminated media
- Determine effectiveness of waste treatment process (e.g., solidification/stabilization)
- Provide basis for landfill design
- Account for biological activity (rarely) in soil column effects
- Deal primarily with large volume, mono-filled wastes

DISTINCTIONS TO BE MADE BETWEEN LEACHING TESTS AND MODELING CONSIDERATIONS FOR REGULATORS AND INDUSTRY

- There is a distinction between leaching tests and partitioning tests:
  - Current leaching tests are standardized regulatory tests not requiring site-specific analyses (e.g., modeling)
  - Partitioning tests are used for data input into mathematical models for site-specific subsurface migration analysis
  - Leaching tests are not for site-specific analysis of contaminant transport
- Regulators and Industry do not want to spend time, money and resources applying leaching tests which are not:
  - Applicable for given conditions
  - Realistic, given site specific conditions type and strength
  - Cannot be used to identify prudent waste management and disposal activities
- "False positives" and "false negatives" are costly from both the regulator and industry point-of-view

PERSPECTIVE OF PUBLIC

- Desire for conservatism
- Tests subject to public review
- Reflective of reasonable worst-case environmental transformation

C-7 - CRITERIA AND OBJECTIVES OF LEACHING TESTS AND MODELING CONSIDERATIONS FOR PARTITIONING TESTS FROM THE PERSPECTIVE OF REGULATORS VERSUS INDUSTRY (Continued)

BASIC NEEDS

o A Rational Construct of the Leaching Phenomenon
  - Avoid regulatory expediency, conservatism
  - Aim for well founded approach

o Understand and Clearly Define the Role of Basic Mechanisms
  - Weathering, Dissolution
  - Desorption
  - Diffusion, Permeation
  - Mechanics/Chemistry of Stabilization/Solidification

o Develop a Leachate Test/Model Interface
  - Tests representative of important phenomena
  - Test results usable in diffusion, flow models

o Validate Model Results through Field Studies
  - Realistic Test Cells
  - Actual Disposal Situations

BASIC BELIEFS

o All Materials Leach

o Our Goal Should be an Acceptable Rate of Release To The Environment

o Leachate Tests Provide a Useful Measure of Environmental Availability
  - Excellent predictor of water borne contamination
  - Of Secondary value for volatile emissions

o Leachate Tests Should Fairly Represent the Actual Mechanics in the Field

o Properly Constructed Leachate Experiments Coupled With Technically Sound Analysis of Flow Phenomena Can:
  - Provide environmentally acceptable disposal
  - Define risks posed by contaminated media

EFFECTS OF SOME LEACHATE TEST PARAMETERS

- Waste/Liquid Ratio
  - Most allow equilibrium/saturation
  - Worst case for total dissolved materials
  - Saturation might suppress relative solubility of some constituents

- Leaching Time
  - Most approach equilibrium
  - No residence time/advection relationship unless a column test

- Number of Extractions
  - Single extractions tell little of leaching phenomena
  - Multiple extractions can provide more information
    - Surface Effects
    - Diffusional Fluxes
    - Compositional Changes

- Particle Size
  - Size reduction provides rapid equilibrium, most conservative, but unrealistic results
    - Ignores permeation, diffusion rate
    - Defeats solidification/stabilization mechanisms

- Leaching Medium (Eluant) Composition
  - Organic acids represent specialized case
    - To simulate municipal co-disposal
    - To provide buffered system, stable Ph
    - Acetates, citrates preferentially extract metals
    - May confuse analysis
  - Inorganic acids to represent "acid rain"
    - More realistic for mono-wastes
  - Total acidity
    - Often high to counteract high alkalinity wastes
    - Overestimates rate and amount of neutralization

- Agitation
  - Speeds Equilibrium
  - Not representative of actual conditions

APPENDIX D - CREDITS AND ACKNOWLEDGEMENTS

The Leachability Subcommittee (LS) of the Science Advisory Board's (SAB) Environmental Engineering Committee (EEC) wishes to acknowledge the many people and offices for their numerous contributions to this self-initiated study to arrive at recommendations and rationale for analysis of contaminant release. While listing names provokes the opportunity to miss contributors by omission, we believe that the following contributors to the efforts of the LS and its parent EEC deserve a special "thank-you" and acknowledgement for their time, energies and efforts toward improving this product and the perspective of the SAB members and consultants in this very complex area.

With respect to an information gathering session conducted on February 26, 1990 in which the LS attempted to assess the varied needs of the Agency, the following persons are recognized for their participation in this exercise, as well as participation in the follow-up activities after this session:

Mr. Harry Allen, EPA, Office of Emergency and Remedial Response (OERR), Emergency Response Division (ERD), Edison, New Jersey

Ms. Robin Anderson, EPA, OERR, Hazardous Site Control Division (HSCD), Washington, D.C.

Ms. Joan Blake, EPA, Office of Toxic Substances (OTS), Exposure Evaluation Division (EED), Washington, D.C.

Mr. David Friedman, EPA, Office of Research and Development (ORD), Modeling, Monitoring Systems and Quality Assurance Office, Washington, D.C. (Formerly with the Office of Solid Waste (OSW), Characterization and Assessment Division (CAD))

Ms. Gail Hansen, EPA, OSW, CAD, Washington, D.C.

Mr. Alexander C. McBride, Chief, Technical Assessment Branch, EPA, OSW, CAD, Washnigton, D.C.

Ms. Lynnann Hitchens, EPA, ORD, Office of Environmental Engineering and Technology Demonstration (OEETD), Washington, D.C. (Now with ORD's Waste Minimization, Destruction and Disposal Research Division (WMDDRD) within the Risk Reduction Engineering Laboratory (RREL), Cincinnati, Ohio)

Mr. M. R. Scalf, EPA, ORD, R.S. Kerr Environmental Research Laboratory, Ada, Oklahoma

Mr. Carlton Wiles, Chief, Stabilization Section of the Municipal Solid Waste Residuals Branch,WMDDRD, RREL, ORD, EPA Cincinnati, Ohio.

Mr. Christopher Zarba, EPA, Criteria and Standards Division (CSD), Office of Water Regulations and Standards (Now known as the Health and Ecological Criteria Division, Office of Science and Technology), Washnigton, D.C.

Dr. Linda E. Greer, Natural Resources Defense Council, Washington, D.C. (At the time she was with the Hazardous Waste Treatment Council (HWTC), but represented herself at the meeting, and not the HWTC)

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APPENDIX E - GLOSSARY OF TERMS AND ACRONYMS

AET ----- APPARENT EFFECTS THRESHOLD
ANS ----- AMERICAN NUCLEAR SOCIETY
ANSI ---- AMERICAN NATIONAL STANDARDS INSTITUTE
ARARSs -- APPLICABLE OR RELEVANT AND APPROPRIATE
ASTM ---- AMERICAN SOCIETY OF TESTING MATERIALS
AVS ----- ACID VOLATILE SULFIDE
BDAT ---- BEST DEMONSTRATED ACHIEVABLE TECHNOLOGY
C ------- CENTIGRADE
CERCLA -- COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION AND LIABILITY ACT (ALSO KNOWN AS "SUPERFUND")
CWA ----- CLEAN WATER ACT
DI ------ DEIONIZED
DLT ----- DYNAMIC LEACH TEST
EDTA ---- ETHYLENE DIAMINE TETRAACETIC ACID
EEC ----- ENVIRONMENTAL ENGINEERING COMMITTEE (SAB/EPA)
EP ------ EXTRACTION PROCEDURE TOXICITY
EPA ----- U.S. ENVIRONMENTAL PROTECTION AGENCY (US EPA, or "THE AGENCY")
EPACML -- EPA COMPOSITE MODEL FOR LANDFILLS
FOWL™ -- FOSSIL FUEL COMBUSTION WASTE LEACHING
HELP ---- HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
IAEA ---- INTERNATIONAL ATOMIC ENERGY AGENCY
ISO ----- INTERNATIONAL STANDARDS ORGANIZATION
K_d ------ DISTRIBUTION COEFFICIENT
LS ------ LEACHABILITY SUBCOMMITTEE (EEC/SAB/EPA)
M ------- MOLE (MOLARITY)
MCC ----- MATERIAL CHARACTERISTIC CENTER
MEP ----- MULTIPLE EXTRACTION PROCEDURE
MEQ/G --- MILLI EQUIVALENT PER GRAM
MIN ----- MINUTE
ML ------ MILLILITER
MM ------ MILLIMETER
MWEP ---- MONOFILL WASTE EXTRACTION PROCEDURE
OMMQA --- ORD/OFFICE OF MODELING, MONITORING, AND QUALITY ASSURANCE, US EPA
N ------- NORMAL (NORMALITY)
N/A ----- NOT APPLICABLE
NCP ----- NATIONAL CONTINGENCY PLAN
NRC ----- NUCLEAR REGULATORY COMMISSION
OMMQA --- OFFICE OF MODELING MONITORING AND QUALITY ASSURANCE, ORD/EPA
ORD ----- OFFICE OF RESEARCH AND DEVELOPMENT, US EPA
OSW ----- OFFICE OF SOLID WASTE, US EPA
OTS ----- OFFICE OF TOXIC SUBSTANCES, US EPA
OSW ----- OFFICE OF SOLID WASTE, US EPA
OTS ----- OFFICE OF TOXIC SUBSTANCES, US EPA
OWEP ---- OILY WASTE EXTRACTION PROCEDURE
PCB's --- POLYCHLORINATED BIPHENYLS
pH ------ NEGATIVE LOG OF HYDROGEN ION CONCENTRATION
PMN ----- PRE-MANUFACTURING NOTIFICATION
R&D ----- RESEARCH AND DEVELOPMENT
RCRA ---- RESOURCE CONSERVATION AND RECOVERY ACT
RSKERL -- R.S. KERR ENVIRONMENTAL RESEARCH LABORATORY, US EPA

APPENDIX E- GLOSSARY OF TERMS AND ACRONYMS - Continuation

SAB ----- SCIENCE ADVISORY BOARD (EPA)
SC ------ OFFICE OF WATER, SEDIMENT CRITERIA PROGRAM, US EPA
SF ------ SUPERFUND PROGRAM, US EPA
SPE ----- SOLID PHASE EXTRACTION
SPLP ---- SYNTHETIC PRECIPITATION LEACHING PROCEDURE
S/S ----- SOLIDIFICATION/STABILIZATION
SYN ----- SYNTHETIC (IN REFERENCE TO SYNTHETIC LANDFILL LEACHATE)
TC ------ TOXICITY CHARACTERISTIC
TCLP----- TOXICITY CHARACTERISTIC LEACHING PROCEDURE
THF ----- TETRAHYDROFURAN
TIE ----- TOXICITY IDENTIFICATION EVALUATION
TSCA ---- TOXIC SUBSTANCES CONTROL ACT
μM ------ MICRO MOLES
UNIFAC -- UNIVERSAL FUNCTIONAL ACTIVITY COEFFICIENT MODEL
WET ----- WASTE EXTRACTION TEST